United States
Environmental Protection
Agency

An Alternatives Assessment for the Flame Retardant Decabromodiphenyl Ether (DecaBDE)

Chapter 1

Introduction

FINAL REPORT

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1 Introduction

1.1 Background

As part of its effort to enhance the Agency's current chemicals management program, U.S. Environmental Protection Agency (EPA) has taken steps to identify chemicals that may pose environmental and health concerns; in 2009-2011 EPA developed action plans to investigate potential regulatory and voluntary actions. In December 2009, EPA released the Polybrominated Diphenyl Ethers (PBDEs) Action Plan[1] that summarizes hazard, exposure, and use information for three commercial PBDE mixtures, including decabromodiphenyl ether (decaBDE). DecaBDE is a flame retardant used in a variety of applications, including textiles, plastics, wiring insulation, and building and construction materials.

As described in the Action Plan, EPA's Design for the Environment (DfE) Program initiated this multi-stakeholder partnership alternatives assessment: *Flame Retardant Alternatives for Decabromodiphenyl Ether (decaBDE).* DfE's partnerships provide a basis for informed decision-making by developing an in-depth comparison of potential human health and environmental impacts of chemical alternatives. The DfE Alternatives Assessment reports provide information of interest to a number of stakeholder groups interested in chemical hazards. As part of the partnership on flame retardant alternatives to decaBDE, representatives from industry, academia, federal and state governments, and non-governmental organizations (NGOs) engaged with DfE to select and evaluate flame retardant alternatives to decaBDE and develop this report. This report is intended to provide information that will enable the selection of safer alternatives to decaBDE, for a variety of products.

DecaBDE has been used at high volume in a broad range of products, but is now being phased out in the U.S. by its manufacturers (U.S. EPA 2010a). The process leading to the phase-out began with EPA's Voluntary Children's Chemical Evaluation Program (VCCEP)[2]. The VCCEP developed industry-sponsored screening level risk assessments for pentaBDE, octaBDE, and decaBDE to evaluate the potential risks to children and prospective parents from potential PBDE exposures (U.S. EPA 2009a). In August 2005, EPA released its Data Needs Decision documents on PBDEs (U.S. EPA 2009a). For decaBDE, EPA indicated a need to further understand fate and transport of decaBDE in the environment, particularly with respect to the significance of its breakdown products, as this could relate to its risk characterization (U.S. EPA 2005). The decaBDE data needs were not met by the VCCEP sponsors and decaBDE was subsequently terminated from the VCCEP program (U.S. EPA 2009a). EPA then announced its intention to proceed with a test rule under Toxic Substances Control Act (TSCA) section 4 (U.S. EPA 2009a). Before a test rule was proposed, the main manufacturers or importers volunteered to phase out manufacture, import and sales of decaBDE (U.S. EPA 2009a).

The use of decaBDE was restricted in particular electrical and electronic equipment under the European Union Restriction of Hazardous Substances Directive, with some exemptions (Council

[1] The Polybrominated Diphenyl Ethers (PBDEs) Action Plan is available online at: http://www.epa.gov/opptintr/existingchemicals/pubs/pbdes_ap_2009_1230_final.pdf
[2] Information on VCCEP is available at: http://www.epa.gov/oppt/vccep.

of the European Union 2003; Council of the European Union 2011). Additionally, in the U.S., the states of Maine, Maryland, Oregon, Vermont, and Washington have imposed restrictions on the manufacture and/or use of decaBDE in certain applications (Washington 2006; Oregon Legislative Assembly 2009; Vermont 2009; Maine 2010; Maryland 2010). Some additional states have proposed legislation restricting the manufacture and/or use of decaBDE; up-to-date information on state regulations can be found in the U.S. State-level Chemicals Policy Database maintained by the Lowell Center for Sustainable Production: http://www.chemicalspolicy.org/chemicalspolicy.us.state.database.php (Lowell Center for Sustainable Production: University of Massachusetts Lowell 2012). In the private sector, the retailer Wal-Mart has reported that they banned the purchase of all consumer products containing PBDEs, including decaBDE, from their suppliers (Layton 2011).

DecaBDE is effective in meeting fire safety standards for plastics and textiles that are used for the manufacture of consumer electronics, appliances, wire and cable insulation, building materials (flooring, wall coverings, and roofing), seating, electronics and paneling for cars, buses and airplanes, and storage and distribution products including plastic shipping pallets. Few potential alternatives to decaBDE are "drop-in" replacements (those that require negligible process changes). Use of alternatives may necessitate additional changes in product formulation or movement to different classes of polymers. As companies that have been using decaBDE in their products prepare for the phase out, this alternatives assessment will be an important resource. The information will help reduce the potential for the unintended consequences that could result if functional, but poorly understood alternatives are chosen.

This alternatives assessment evaluated flame retardant alternatives judged by knowledgeable stakeholders[3] as most likely to be used in applications that previously had been filled by decaBDE. This report did not evaluate efficacy of these alternatives in regards to specific materials, product applications or related standards; stakeholders provided professional judgment about whether chemicals are likely to meet flammability tests in various uses. The alternatives included in this assessment are potentially viable[4] and functional but not necessarily preferable. Selection of a chemical for evaluation in the report does not denote preferability in terms of environmental or health hazard, or any other metric. Rather, the report provides information that will help decision makers consider environmental and human health profiles for available alternatives, so that they can choose the safest possible functional alternative. This information focuses on the potential hazard associated with a particular chemical. This report also presents general information on exposures to flame retardants, life-cycle considerations, and economic, performance, and social factors. The report provides information that will enable informed selection of alternative flame retardants to decaBDE.

Assessments of alternatives to decaBDE have been conducted by several organizations in the past, including the Swedish Chemicals Inspectorate, European Commission, Danish Ministry of

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[3] In particular, chemists and engineers at ADEKA Corporation, Albemarle, Amfine Chemical Corporation, BASF, Boeing, Clariant, Eagle Performance Products, FRX Polymers®, Inc., Great Lakes Chemical – A Chemtura Company, PolyOne, TSG Finishing, University of Dayton ICL Industrial Products, University of Dayton Research Institute, and University of Massachusetts – Lowell.

[4] Viability refers to the functional performance of a chemical as a flame retardant in certain plastics, not the environmental preferability of the chemical.

the Environment, State of Illinois, State of Washington, Clean Production Action, and the University of Massachusetts at Lowell (Pure Strategies Inc. for the Lowell Center for Sustainable Production 2005; Illinois Environmental Protection Agency 2006; Clean Production Action 2007; Danish Ministry of the Environment 2007; European Chemicals Bureau 2007; Washington State Department of Health 2008; Pure Strategies Inc. for Maine Department of Environmental Protection 2010). These assessments looked at decaBDE in a range of applications including television enclosures, other electrical and electronic equipment, textiles, residential upholstered furniture and plastics. A few of the studies acknowledged a lack of key information on a number of chemicals, which prevented them from conducting a full hazard assessment of the potential alternatives. In this alternatives assessment report, DfE filled gaps with modeled data estimations and expert judgment, and included assessment of new-to-market decaBDE alternatives.

1.2 Purpose of the Flame-Retardant Alternatives Assessment

The purpose of this alternatives assessment is to identify potentially functional and viable alternatives for decaBDE, evaluate their human health and environmental profiles, and inform decision makers in order for organizations to choose safer alternatives to decaBDE.

1.3 Scope of the Flame-Retardant Alternatives Assessment

The partnership refined the scope of this assessment from the PBDEs Action Plan with information supplied by experts in industries that use decaBDE in their products and from academics, NGOs and government participants. The assessment provides hazard information (human toxicity, ecotoxicity and environmental fate) on flame retardants that were selected for evaluation in this report as potentially functional alternatives to decaBDE. While this project is not designed to recommend specific flame retardants, it does evaluate potential alternatives to decaBDE that have the potential to be functional and viable in certain applications. Therefore, this evaluation can support informed substitution and has the potential to identify environmentally preferable substitutes.

The partnership on flame retardant alternatives to decaBDE is an assessment of hazards of flame retardant chemicals that are potentially functional and viable[3] alternatives to decaBDE. These alternatives have the potential to enable a product to meet relevant flammability standards when used in one or more of the material classes listed below. These materials include those in which decaBDE is currently used or was used in the past. Additionally, polycarbonate (PC) and polycarbonate-acrylonitrile butadiene styrene (PC-ABS) were included because they can be used with some of the alternative flame retardants. The material types that are most relevant to this project include:

1. Polyolefins
   a. Polypropylene
   b. Polyethylene
   c. Ethylene vinyl acetate (EVA)

2. Styrenics
   a. High-impact polystyrene
   b. Acrylonitrile butadiene styrene

3. Engineering thermoplastics
   a. Polyesters
      i. Polybutylene terephthalate
      ii. Polyethylene terephthalate
   b. Polyamides, e.g., nylon
   c. PC and PC blends, e.g., PC-ABS
   d. Polyphenylene ether – high-impact polystyrene

4. Thermosets
   a. Unsaturated polyesters
   b. Epoxies (electronics, building and aerospace applications)
   c. Melamine-based resins

5. Elastomers
   a. Ethylene propylene diene monomer rubber
   b. Thermoplastic polyurethanes
   c. EVA

6. Waterborne emulsions and coatings – including but not limited to those designed for textile back coatings such as:
   a. Acrylic emulsions
   b. Polyvinyl chloride emulsions
   c. Ethylene vinyl chloride emulsions
   d. Urethane emulsions

The scope was outlined in terms of categories of materials rather than specific applications or end-use products because decaBDE has many varied applications. In this approach, the partnership intended to provide toxicity and environmental fate information on potential flame retardant alternatives for product manufacturers who must make substitution decisions, as well as for other interested or affected parties (e.g., end users, downstream processors).

The alternative flame retardant chemicals[5] will be evaluated for hazard potential independent of the materials in which they might be used or incorporated. While the assessment will not attempt to include comprehensive life cycle assessment (LCA) information, it will, by both inclusion and by reference, note relevant life-cycle considerations that may aid in the selection of alternatives. Due to these constraints, this assessment does not provide all of the information that a decision maker may need to be able to choose an alternative flame retardant.

The report is organized as follows:

[5] For the purposes of this report, ‘chemicals’ include both discrete substances that can be represented by a definite structural diagram (such as methane) and reaction mixtures that cannot. Reaction mixtures include those that are well defined with a few components (such as propylene glycol), mixtures that may be difficult to characterize and/or are of variable composition (such as polychlorinated biphenyls or Aroclors), and polymers.

- *Chapter 1 (Introduction):* This chapter provides background on the Partnership on Flame Retardant Alternatives to decaBDE project, including the purpose and scope of the partnership and of this report.

- *Chapter 2 (Products and Materials):* This chapter describes the products and materials in which decaBDE has been used, as well as technical information about flammability standards and other performance criteria.

- *Chapter 3 (Background on Flame Retardants):* This chapter describes chemical flame retardants generally, as well as those specific to this assessment.

- *Chapter 4 (Evaluation of Flame Retardants):* This chapter explains the chemical assessment method used in this report and summarizes the assessment of hazards associated with each flame retardant chemical.

- *Chapter 5 (General Exposure Information and Life Cycle Considerations):* This chapter includes potential exposure pathways associated with flame retardants along each stage of their life-cycle and resources for life cycle impact information that decision makers may need.

- *Chapter 6 (Considerations for Selecting Flame Retardants):* This chapter summarizes the results of the assessment and identifies human health, environmental, economic, performance and social considerations for selecting alternative flame retardants.

1.4 Chemical Alternatives Assessment as a Risk Management Tool

Among other actions, the Agency chose to conduct an alternatives assessment as a suitable risk management tool for decaBDE in the PBDEs Action Plan. The Agency chose this tool to inform the chemical substitution that may occur as an outcome of other activities described in the Action Plan. Chemical alternatives assessments provide information on the environmental and human health profiles of chemicals that may be used as substitutes so that industry and other stakeholders can use this information, in combination with analyses of cost, performance, and other factors to choose alternatives.

Chemical alternatives assessment, LCA, and risk assessment are all tools that can be used to improve the sustainability profiles of chemicals and products. These tools, which can be complementary, should be selected according to the ultimate action they are intended to support and other regulatory and policy considerations. DfE alternatives assessments establish a foundation that other tools, such as risk assessment and LCA, can build upon.

The focus of this DfE alternatives assessment report is a comparative hazard assessment of the chemical alternatives that may be substituted for decaBDE in a variety of uses. Comparative chemical hazard assessment is a comparison of chemicals within the same functional use group (e.g., solvent, surfactant, flame retardant, ink developer) that evaluates alternatives across a consistent and comprehensive set of hazard endpoints. Information about chemical hazards derived from this type of comparative chemical hazard assessment can be used by decision-makers, in combination with other inputs, such as information on cost and performance, to select safer alternative chemicals.

In many cases, the hazard status of chemicals included in DfE Alternatives Assessments is not fully characterized by empirical data. A full data set would improve any assessment. Unfortunately, a full empirical data set is not available for most chemicals. Because EPA authority to require data is limited (e.g., EPA has no minimum measured data requirements for new chemicals (U.S. EPA 2009b; U.S. EPA 2010b)) and because developing such data is expensive and takes time, EPA has developed a suite of predictive modeling tools to estimate chemical hazard (U.S. EPA 2010b). EPA uses modeled data and subject matter expertise to fill data gaps for the TSCA new chemicals program when little or no experimental data are submitted. Although modeled data should be interpreted with care, when combined with available empirical data, the data set comprises the best available information. Even with a reliance on modeled data for some endpoints information from DfE Alternatives Assessment can support decision making concerning safer alternative chemicals.

Risk assessment and alternatives assessment are both based on the premise that risk is a function of hazard and exposure. Risk assessment characterizes the nature and magnitude of hazard and exposure from chemical contaminants and other stressors. The DfE alternatives assessment evaluates and compares the nature of the chemical hazards and reflects a view that when exposure is comparable, risk is reduced through the use of less hazardous chemicals. Alternatives assessment strives to decrease the reliance on exposure controls thus reducing risk even when exposure controls fail.

Chemical alternatives assessment differs substantially from LCA. An LCA can present a robust picture of many environmental impacts associated with the material and energy inputs and outputs throughout the life cycle of a product, and by doing so can identify opportunities for reducing those impacts. However, unlike chemical alternatives assessment, LCA typically provides a limited (if any) review of inherent toxicity.

DfE's 'functional use' approach to alternatives assessment orients chemical evaluations within a given product type and functionality. Under this approach, factors related to *exposure scenarios*, such as physical form and route of exposure, can be constant within a given functional use analysis and will fall out of the comparison so that a reduction in hazard is a reduction of risk. When less hazardous alternatives have different physical-chemical profiles or require different use levels, it may be appropriate to also conduct an exposure assessment. DfE alternatives assessments consider intrinsic properties of chemical substitutes that affect *exposure potential*, including absorption potential, persistence, and bioaccumulation. Under this approach, the health and environmental hazard profiles in the alternatives assessments become the key variable and source of distinguishing characteristics. Information on key properties that can be used to evaluate significant differences in environmental fate and transport, including persistence, bioaccumulation, and physical properties, are included in Chapters 4 and 5.

Chemical alternatives assessment is most useful in identifying safer substitutes when available alternatives meet performance requirements and are expected to present lower hazards for human health and the environment. This report relied on literature review and expert stakeholders to select the chemicals now included in this report. These chemicals were chosen as likely, but not necessarily proven, functional alternatives. While their performance in specific products must be verified, the information in Table 3-2 of this report on functionality is, at a minimum, a good start to understanding which alternatives might be valuable for a given functional use. Although the information in Table 3-2 does provide useful information, performance and efficacy of the alternatives are not the primary focus of this report. Product manufacturers transitioning to new flame retardants may have to test a number of chemicals or chemical combinations to determine if they meet performance requirements in final products. During decision-making, risk assessment or LCA could be applied to the lower-hazard or potentially preferable alternatives to complement the alternatives assessment findings. Alternatives assessment can identify scenarios in which initial comparisons indicate that there may be no preferable alternatives to the chemical being considered. However, this can guide innovation and product development by understanding the characteristics of a safer alternative.

The DfE chemical alternatives assessment approach is aligned with green chemistry principles[6]. Two of those principles are especially noteworthy:

- Principle 4: Design of safer chemicals – "Chemical products should be designed to effect their desired function while minimizing their toxicity," and

- Principle 10: Design for degradability – "Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment."

DfE incorporates these two green chemistry principles in its criteria and applies them in its assessment of chemical hazard and fate in the environment. This approach enables identification of safer substitutes that emphasize greener chemistry and points the way to innovation in safer chemical design where hazard becomes a part of a performance evaluation.

[6] http://www.epa.gov/sciencematters/june2011/principles.htm

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